I. C. 6923 OCTOBER 1936

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
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SHAFT SINKING WITH A SHOT DRILL, IDAHO MARYLAND MINE, GRASS VALLEY, CALIF.

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BY

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SHAFT SINKING WITH A SHOT DRILL, IDAHO MARYLAND MINE, GRASS VALLEY, CALIF.[1]

By J. B. Newsom[2] and C. F. Jackson[3]

INTRODUCTION

This is one of a series of circulars dealing with mining methods, practices, and costs. It describes the method of sinking a shaft 60 inches in diameter with a shot drill, as employed at the Idaho Maryland mine, Grass Valley, Calif. The operation involved a great deal of experimentation in applying the shot-drill method to large bore drilling, overcoming mechanical and other difficulties which developed during sinking, and developing operating technique. Under such circumstances, costs are obviously higher than they would be after the pioneer work has been done, but even so, these actually obtained compare favorably with costs of sinking by more conventional methods.

ACKNOWLEDGMENTS

The authors are indebted to Mr. Errol McBoyle, president of the Idaho Maryland Mining Co., not only for his cooperation and advice during the sinking of this experimental shaft, but for permission to prepare this article for publication with the inclusion of cost data.

PURPOSE OF SHAFT

A new shaft was required at the Idaho Maryland mine to serve for ventilation and supply purposes. A circular shaft is ideal for ventilation because it furnishes for a given area a minimum area of rubbing surface and hence, a minimum frictional loss. For cage purposes, where one compartment only is to be employed, a circular shaft often gives, except for handling rectangular containers, a maximum ratio of useful cage area to the total area of the shaft.

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6923".

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The senior author previously had considerable experience drilling with shot drills[4] and had sunk one large-diameter hole in connection with wire-saw work. With deep holes of large diameter, considerable trouble was experienced because of the drill rods whipping in the hole. Considerable time is lost connecting and disconnecting the rods, and a long string of rods is expensive. These considerations led the senior author to design a drill with the drive mechanism and core barrel close-connected so that they could be lowered into the hole together. The third purpose of this shaft, then, was to develop equipment and operating technique based on this design.

NATURE OF GROUND

At the site selected for the shaft, it was anticipated that the ground to be penetrated would be mostly serpentine. A log of the formations penetrated is as follows:

Feet
0 - 44 --- Alluvium, mined by hand and square-set.
44 - 180 --- Gabbro.
180 - 182 --- Fault.
182 - 415 --- Serpentine, blocky, increasingly treacherous at greater depths - contained several diabase dykes.
415 - 470 --- Ankerite, very heavy and treacherous.
470 - 710 --- Serpentine, generally firm.
710 - 750 --- Fault material, streaked with heavy gouge seams.
750 - 1080 --- Serpentine.
1080 - 1110 --- Treacherous serpentine.
1110 - 1125 --- Serpentine.

The serpentine as encountered in the mine generally stands well except where shattered by faulting or highly altered, and it was believed that a drilled shaft would have an additional advantage in that there would be no heavy blasting to shatter the walls of the shaft, and that, therefore, the drilled shaft would probably stand for the most part without lining.

Drilling characteristics of the various materials were as follows:

Gabbro - drilled 6 to 10 inches per hour, produced cuttings which packed firmly and caused some difficulty in removing cores.

Upper fault zone - caused delay due to inexperience. The lower fault zone was drilled without difficulty.

Serpentine - drilled 12 to 20 inches per hour, produced colloidal sludge which did not hamper the other operations.

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[4] Newsom, J. B., and Bowles, Oliver, A New Adaptation of a Wire Saw: Eng. and Min. Jour., vol. 124, no. 12, December 1933, pp. 506-508.

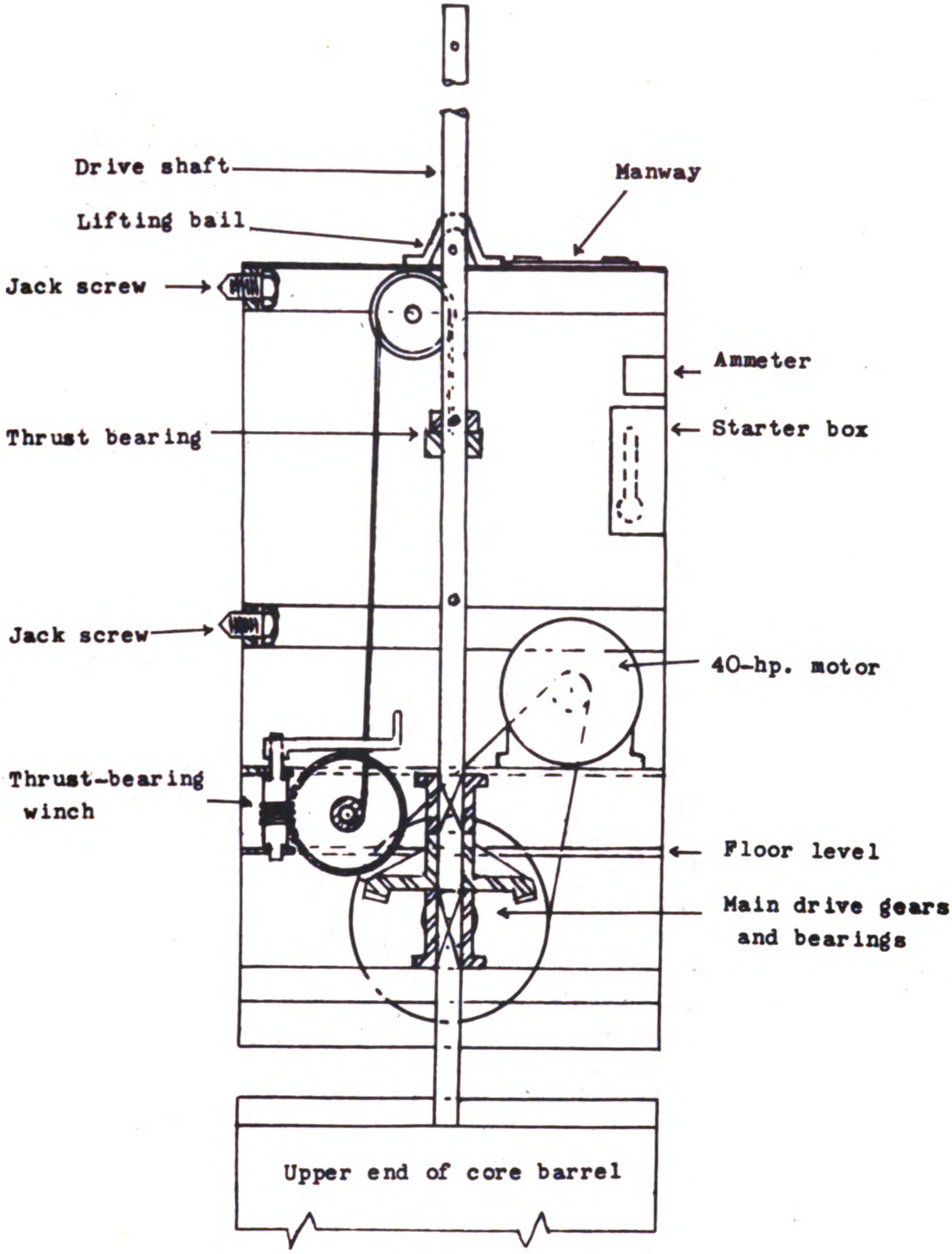

Figure 1.- Generalized cross-section of shaft drill.

Ankerite and Treacherous Serpentine - drilled 8 to 15 inches per hour, but pieces from the walls often slipped in against the core barrel and retarded operations.

The average length of core during most of the work was 7 feet, but in the heavy ground the average core length was not over 5 feet, due to these slipping blocks.

DESCRIPTION OF EQUIPMENT AND MODE OF OPERATION

The job was started with an ordinary tripod, and an air hoist on the surface, and with only the drill and core barrel for the drilling operation. As the work progressed, various needs for auxiliary equipment developed and were filled. When the job was in its last stages, the equipment employed included the following major items:

Surface Equipment

Standard wooden headframe - consisting of 12- by 12-inch timbers; height of headframe, 83 feet.

Hoist - 150 hp., double-drum; rope speed, 600 feet per minute.

Power cable reel - A converted steel hoist with a 20-hp. motor, the flanges built up so the reel carried 1,150 feet of 3-conductor, rubber-covered power cable.

Core-handling arrangements - consisting of a drawbridge which could be lowered over the drillhole, and a wooden platform car. In operation, the cores were hoisted above the collar, the drawbridge was lowered, and the car was pushed under the core, which was then lowered onto the car and pulled to the dump.

Underground Equipment

The drill consisted of the two parts, the driving mechanism and the core barrel. These were assembled as a single unit which was lowered into the hole. The drive mechanism was assembled in a circular cab which contained room for the drill runner, and the cab was kept from rotating by screw jacks which could be set against the walls.

The unit was driven by a 40-hp. motor, with reduction gears to give a core-barrel speed of 60 revolutions per minute.

The core barrel was 15 feet long, with a cutting shoe $1\frac{1}{2}$ inches thick by 12 inches high attached to the lower end. The outside diameter of the shoe was 59-9/16 inches.

The actual cutting was done by chilled shot. No attempt was made to use other cutting media, such as insert teeth, or angular abrasives.

Auxiliary Underground Equipment

In addition to the regular core barrel, there were two other core barrels, as follows:

The hole deviated from vertical in the heavy ground at a depth of 450 feet. Since deviation in a vertical shaft must be avoided, it was necessary to devise a method of bringing the hole back on line. This was accomplished with a short core barrel, which was fitted with a standard-size shoe, but was enough smaller on the upper end so that the upper end could be held to one side of the drillhole, thus changing the direction. This device proved simple and satisfactory in operation.

The other special core barrel was an experimental barrel built to extract cores when the machine was hoisted to the surface directly after the drilling was completed. This special barrel was not delivered until the job was so nearly completed that experiments with it were not finished. However, enough work was done to demonstrate that such a barrel can be employed and will probably be used on future work in blocky ground.

In addition to the drilling mechanism and core barrels, there was a core puller consisting of a tapered ring and a number of fluted dogs. This was designed in such a way that it could be lowered around a core and when hoisting pressure was put on the core puller, the dogs would contract and grip the rock. After cores were removed there was always a certain amount of loose rock in the bottom of the hole. This was removed in an ordinary half-ton mucking bucket fitted with a safety hood. The hood was attached to the bucket in such a way that the bucket and hood were a unit, and the hood could not be lowered onto a man in the bucket or standing beside it. Water was handled with an ordinary clack-valve bailing bucket holding about 150 gallons of water. When the drill was in the hole, men were raised or lowered in a torpedo-shaped steel shell, 22 inches wide by 14 inches thick by 7 feet long, pointed on each end. A supply of fresh air in the bottom of the hole was required, and this was furnished by running compressed air through a half-inch hose which was lowered and raised by hand.

An ordinary bell-signal system was used, with special signals to fit the job.

Cycle of Operations

The drilling cycle was as follows:

1. Lower and line up the drill.
2. Drill.
3. Hoist drill from hole and move to one side.
4. Bail water and cuttings.
5. Lower core lifter, break off core, and hoist and dump core.
6. Bail water and cuttings.
7. Inspect and clean the bottom of the hole.
8. Run in 8 feet of water in preparation for next drilling cycle.

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SAFETY RECORD

Safety precautions consisted mainly of continual care in training men. For example, there was always an apprentice on the crew. Safety belts were worn whenever men were riding up and down the shaft. Blasting, occasionally required to break the cores, was all done by electricity, with the men on the surface. No men were ever hoisted with heavy loads. The walls of the shaft were inspected and tested once each week from top to bottom for loose ground, and the general rule was never to do anything else when something could be done to increase the safety of the operation. Where loose ground was encountered, it was made safe before any operations were carried below. The result of these policies was to complete the hole with but one accident, and this only a simple leg fracture. Due to the small number of men, it was possible to supervise the entire operation closely and give thorough training to each man employed.

COSTS

Following is given the total cost of the 1,125 feet of shaft, including the plant (materials and labor of installation and erection) and the direct sinking cost, as taken from the books of the company:

Surface plant

Headframe, hoist house, and change house	$4,670.10
Transformers and 40-hp. motor	576.31
2-in. and 4-in. air pipe	660.24
150-hp. hoist (second hand)	3,681.16
1 double-drum tugger hoist	285.00
Tugger hoist	152.29
Lighting and signal systems	229.88
Total plant	$10,254.98
Shaft Boring Equipment	5,333.58
Total plant and shaft boring equipment	15,588.56

Shaft Boring Operation

Following is the cost of actual sinking operations:

Labor	$17,368.96	
Supplies	4,847.54	
Power	1,061.11	
Miscellaneous	3,248.24	
Total operation		26,525.85
Grand total plant, equipment, and operation		42,114.41

Shaft Boring Operation, cost per foot
(Depth of shaft, 1,125 feet)

	Cost per foot
Labor	$15.44
Supplies	4.30
Power	.94
Miscellaneous	2.89
Total	23.57

The above direct operating cost per foot does not include depreciation on the equipment. It does include the following items:

All direct labor and supervision, including hoistmen - also including the labor spent in supporting the walls where necessary.

Supplies - includes all direct drilling supplies, such as shot, drill shoes, small tools, oil and grease, and sand and cement for concrete.

Power - this item was taken from the company's distribution sheets. The power was not metered. The various motors in use have been mentioned above.

"Miscellaneous" consists principally of repair parts to the drilling and other equipment, and shop costs.

In considering the probable future costs, it must be remembered that the total costs covered the experimental periods, as well as the more satisfactory sinking periods. The experience gained in sinking this shaft covered so many types of ground that with holes 5 feet in diameter this experimental lost time should be greatly reduced in the future. The direct sinking costs should be further decreased by the use of heavier, better-powered equipment, and improvements in handling technique.

During the 35-day period from July 23 to August 27, 1935, the operation was comparatively free from experimental lost time and equipment failures. The figures obtained during that period follow:

Period covered: July 23 to August 27, 1935.

Depth sunk: 160 feet (545 to 705 feet).

Material: Blocky serpentine, with some ankerite.

Labor and Supervision:	Cost per foot	
Setting and removing drill	$1.39	
Drilling	2.21	
		$3.60
Bailing	.98	
		.98
Mucking cores	2.20	
Removing cores with core puller	1.44	
		3.64
Drill maintenance & repairs	.20	
Cementing walls	.51	
Lost time	1.17	
		1.88
TOTAL LABOR AND SUPERVISION		10.10
Crew cost per hour, including bonus	1.92	
Other expenses (see note)		
Drill shoes	1.03	
Power	.50	
Shot	.60	
Concrete and steel for wall support	.17	
Lights, small tools	.15	
Repair parts, experimental supplies & Miscellaneous	1.24	
		3.69
TOTAL DIRECT COST		13.79

Note: The charges marked "Other expenses" are taken from averages of longer periods, as the books were not balanced at the beginning and end of the drilling period under discussion.

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The labor cost in crew-hours per foot of shaft during this period was as follows:

	Crew-hours per foot
Setting and moving drill	0.723
Drilling	1.150
Bailing	.509
Mucking broken cores	1.150
Removing cores with core puller	.750
Drill maintenance and repairs	.104
Cementing walls	.265
Lost time	.609
Total	5.260

Those most familiar with the work feel that an average sinking rate of well over 5 feet per day should ultimately be obtained. That this expectation is not entirely unreasonable is indicated by the results for a 3-day period in good ground, as follows:

Footage, 3 days	21 feet
Direct labor, per foot	$6.41
Other charges, per foot	3.74
Total per foot	10.15

Wall Support

It is difficult to give total costs for this part of the operation, because bad places in the walls ranged from small patches to ground so bad that a solid column of reinforced concrete had to be built, with the shaft opening inside of the column. The method used was simply to dig out the bad ground far enough back so a shell of reinforced concrete could be placed in the cavity. Then a lattice of reinforcing bars was built in the opening, an expandible form was placed, and cement was poured behind the form. 24-hour cement, quickened with 2 percent of $CaCl_2$, was used for this work. During one period when a large proportion of the time was spent on wall support, careful records of time and materials were kept. They showed approximate costs of $10.00 per foot of shaft for labor and $2.50 per foot for materials, a total of $12.50 per foot for the portion cemented.

Organization of Crew and Wages

The crew consisted of eight men, as follows:

1 foreman
3 drill runners (1 for each shift)
3 helpers (" " " ")
1 apprentice

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Drill runners were paid \$5.20 per day, helpers \$4.40 per day, and the apprentice \$4.40 per day. The footage sunk was measured twice a month and a bonus of \$1.00 per foot was divided among the drill runners and helpers in accordance with the amounts earned. The apprentice and the foreman did not share in this bonus. At the beginning of the work, labor turnover was high, but during the last six months there were no changes in personnel.

COMPLETED SHAFT

Guide Installation, Cages, Conduits, etc.

Steel shaft guides hung on stud bolts were installed. The guides were set 1-1/2 inches from the walls, so electric conduit could be placed behind them. Since the walls are smooth, the guides were easily alined and were fastened to stud bolts set in drill holes.

The cage was built with three detachable decks, each of which will accommodate 10 men comfortably. There was some question as to the efficiency of steel safety dogs on steel guides. However, the cage was tested empty and with a ton weight, and the dogs found to hold. The method of testing was to suspend the cage from a hemp rope, which was then sawed in half.

The cage contains an electric light, and signal knocker. Power for these is transmitted inside the cage through a trolley at a potential of 32 volts.

A 2-inch, fresh-water line extends down the shaft, and it is planned to run a 4-inch air column. The mine water is pumped at the main shaft.

The cage is circular in cross-section, with 2-inch wall clearance, and the sides are flattened to make room for the guides. The effective area is quite large, as follows:

Area of opening	19.7 sq. ft.
Cage area	15.8 " ".
Percent effective	80.1 percent

APPLICATION OF METHOD

Future work may be expected to define the boundaries of application of the boring method and possibly to enlarge the field. However, based on present results the following limits seem indicated:

Diameters - between 2 feet 6 inches and 6 feet.
Depths - not less than 100 feet, not over 1,500 feet without cutting stations.

CONCLUSIONS

Ground Characteristics

Experience of others, and the previous experience of the senior author in drilling stratified and creviced ground and in drilling ground containing cavities, shows that such ground can be handled satisfactorily. Hard ground does not greatly delay the operation. Ground support may, of course, add to the cost, as it would in any type of sinking operation.

Water Conditions

This is an unknown factor at present. The shaft described in the foregoing pages made about 7,000 gallons of water per day. Methods of handling heavy flows of water have been worked out on paper, but they have yet to be proved in actual operation.

Inclined Holes

The writers have not had experience with inclined shot drill holes.

A group of Holes

Since the helpers are idle most of the time, it would seem that a single helper could serve two or more drill runners. A foreman could easily look after two or more such holes. Thus, a group of holes, to produce in effect a two- or three-compartment shaft, apparently would not cost two or three times as much as a single hole.